Aquatic Botany 132 (2016) 5–11

Contents lists available at ScienceDirect

Aquatic Botany

journal homepage: www.elsevier.com/locate/aquabot

Water quality change in the Mississippi River, including a warming river, explains decades of wetland plant biomass change within its Balize delta

David A. White[a,*], Jenneke M. Visser[b]

[a] Department of Biology, Loyola University New Orleans, New Orleans, LA 70118, USA
[b] Institute for Coastal and Water Research, and School of Geosciences, University of Louisiana at Lafayette, Lafayette, LA 70504, USA

ARTICLE INFO

Article history:
Received 27 February 2015
Received in revised form 26 February 2016
Accepted 29 February 2016
Available online 2 March 2016

Keywords:
Balize delta
Climate change
Biomass change
Freshwater wetlands
Land use change
Long-term study
Louisiana
USA
Mississippi River
River water quality
Warming river

ABSTRACT

Ecosystem properties of riverine wetlands are known for high inter-annual variability. This multi-decadal study within the wetland complex of the Mississippi River's Balize Delta, USA assesses how river parameters (temperature, discharge, and sediment load) impact wetland plant biomass over time and space. The Mississippi River's annual temperature has increased 0.9 °C/decade, while discharge and sediment load has varied without trend over the same period. End-of-season herbaceous biomass increased 14 g/m^2/year between 1988 and 2008, extrapolating to large (m-ton) area-wide increases. The river's temperature, discharge and sediment impacted the Delta's biomass in two ways: the increase in temperature had a positive impact on the growing season length which increased biomass; whereas discharge and load had negative impacts affecting the inter-annual variation without a temporal trend. The results explain natural variability in ecosystem processes in a dynamic deltaic system and likely trace a signal related to both climate warming and land use change within the drainage of the Mississippi River. The discovered decadal increase in herbaceous biomass has implications on carbon storage in the inshore and offshore receiving basins of the world's riverine wetlands experiencing longer growing seasons.

1. Introduction

Long term studies of more than two decades are unusual and have significantly contributed to the understanding of the dynamics in ecological patterns and processes with respect to climate (Brown et al., 2001; Peterson et al., 2002; Clark et al., 2003; Müller et al., 2010; Strayer et al., 2014). Throughout the world, river hydrology greatly influences the associated wetland floodplain ecosystems (Junk and Wantzen, 2006). Of particular ecological significance to these wetlands is the quality of the river's flood waters. Coastal wetlands associated with river floodplains are ecosystems at the front lines of ecosystem change brought on by humans (Brinson, 2006).

The larger rivers and deltas of the world are particularly important to carbon cycling and fluxes because of the enormous amounts of carbon transported to the oceans and stored in sediments, even those within the delta sediments proper (Bianchi and Allison, 2009). Changes in the climate and land use across catchments impact important river-water parameters, e.g., temperature, discharge, nutrient levels, and sediment loads. Each of these hydrologic parameters has several quantitative and qualitative components (e.g., amount, seasonality, frequency, duration) that are coupled and relevant to the ecology of the organisms the river touches (Visser et al., 2006; Kaushal et al., 2010).

Numerous studies show that lotic ecosystems around the world have warmed over recent decades and attributed this change to climate warming likely from anthropogenic processes (Arnell and Reynard 1996; Kaushal et al., 2010; van Vliet et al., 2013; Strayer et al., 2014; Tao et al., 2014). They and others show that additionally, through land use change (LUC), the parameters of discharge, sediment, nutrient loads, and pH have changed in rivers (Walling 1999; Rabalais et al., 2002; Foley et al., 2005). Global sediment fluxes have been significantly altered by human activity impacting flood plains, deltas and ocean environments (Syvitski and Kettner, 2011). Also, increasing urbanization will continue into the future to have warm-

* Corresponding author. Current Address: Department of Biology, Loyola University New Orleans, New Orleans, Louisiana 70118, USA.
E-mail addresses: dawhite@loyno.edu (D.A. White), jmvisser22@gmail.com (J.M. Visser).

http://dx.doi.org/10.1016/j.aquabot.2016.02.007

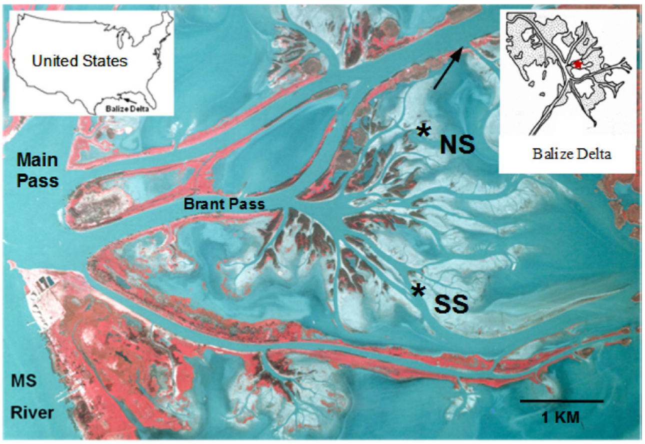

Fig. 1. False-color aerial image of the Brant inner-deltaic Splay within the Mississippi River Balize Delta, Louisiana, USA. Image was taken winter, 1995. NS = North study Site; SS = South study Site. The land-like whitish-blue areas on the image down current from the reddish-brown highest elevated woody lobe areas show the extensive winter-bare mudflats that support the wetland communities like those in the study. The arrow is the point of the constructed crevasse along Octave Pass (see Section 2). Main Pass is one of the 4 principle distributaries of the river at its terminus which carries water northeast to the Gulf of Mexico. The right inset is a line drawing of the entire Balize Delta with the location of the Brant Splay study area (star). The drawing clearly shows the remaining 3 principle passes that branch off in 'bird-foot' fashion to the south. The photo image is showing ~50% of the river's main channel width; its full width here is about ~1.8 km.

ing and discharge affects on streams (LeBlanc et al., 1997). These human caused changes have near and off shore consequences to the receiving seas (Bianchi et al., 2014).

Within the basin of the Mississippi River LUC has impacted discharge (Tao et al., 2014) and appears to be the dominant cause of discharge change at least within the upper basin (Frans et al., 2013). Blum and Roberts (2009) identify that the anthropogenic decline in sediment supply is one of the principal causes of the loss of "Delta Plain" coastline wetlands in Louisiana, a single large delta ecosystem. Worldwide, most delta wetlands are in decline (Coleman et al., 2008).

This study started as a project to document primary succession of plant communities on the delta splays within the Balize Delta (White 1993). After years of sampling to further document wetland change in this highly dynamic system, we used the long-term data to test for environmental controls on biomass. Since these wetlands are in daily contact with Mississippi River waters, we hypothesized that river discharge, temperature and sediment load would have significant impact on the Balize Delta's plant biomass. We expected a positive effect of river temperature on biomass as productivity generally increases with temperature. We were unsure of the effect of discharge and sediment load as these co-vary with higher nutrient inputs to the splays, but they also may raise water levels and bury propagules, respectively, on the splays.

2. Methods

2.1. Study region and history

The Balize Delta of ~500+ years age (Fig. 1 inset) is the last of the five major delta systems that created the landscape of the east-central coast of Louisiana, USA (Roberts, 1997). Even though this delta as a whole is decreasing in area, interior crevasses (natural or man made levee breaches) lead to local land building by often forming "deltaic splays" (miniature landforms in the general shape of deltas) downstream from crevasses. The Brant splay (Fig. 1) is an "inner-delta splay", and now the largest and oldest of the many splays within the Balize Delta. The splay began growth after a shoreline breach along Brant Pass in 1978 and continued rapid growth through 1984 when this study began. This growth was expected to continue for some years more because of the size and configuration of its receiving basin. The Brant splay reached maximum size in the first decade of the 21st century.

On the Brant and other splays within the interior freshwater regions of the Balize Delta there exists remarkable fidelity in patterns of plant colonization, community development, and therefore community persistence associated with elevation change along the gradually sloping lobes of the splays (White 1993; Cahoon et al., 2011). The consistent topographic change is clearly indicated by the presence of specific and highly dominant "foundation" species. The up current lobe-ends of highest elevation support a "Forest" community (of *Salix nigra* Marshall and Composite shrubs), followed down elevation by communities of their specific diagnostic herbaceous species, in order of "High Marsh" of *Schoenoplectus deltarum* (Schuyler) Sokják, "Low Marsh" of *Sagittaria latifolia* Willd., "Lowest Marsh" of *Sagittaria platyphilla* (Engelm.) J.G. Sm.; and then farther down slope of two communities without vascular plants, "Mudflat" (if the lobe is elongating, i.e., accreting with colonizable mud), and "Open Water" (of the receiving basin) with its underwater substrate surface just ~80 cm down slope of the forest floor surface. Each vegetated community type can also support other grasses, sedges or dicots but if so nearly always in low abundance. If the sedimentation balance changes and a site surface subsides or accretes, the local community type will change; a fact that clearly shows their fidelity to narrow elevation range. The change in community type is often rapid within even one to two growing seasons.

2.2. Plant biomass

In 1984, two lobes within the wetland complex of Brant splay were chosen as sites for study: North Site (NS) and South Site (SS; Fig. 1). In late spring, stakes were placed at the distal ends of the elongating lobes after the spring high water period ended which exposed new non-vegetated muds (White 1993). The stakes marked the locations along transects perpendicular to the shoreline where aboveground plant material was sampled each year at the end of the growing season (50 cm × 50 cm plots) to first track primary succession over time. Sampling continued after 1990 until 2008 to record subsequent community change each year.

At the start of the study in 1984, a third site was established to create wetland habitat just down flow of a 1983 constructed crevasse (arrow—Fig. 1; authorized by the Fish and Wildlife Service) along the south shore of Octave Pass. This crevasse was dredged to build mud substrates in the northern portion of the same shallow receiving basin of the Brant Splay. Dredged material did impact the natural vegetation on the selected site post the early succession years (after 1988/89). The results from this third "created" site therefore were omitted from this study.

Following the transect sampling at the SS and NS sites in 1984, two permanent stakes that marked additional transects at the sites were added during later early springs as the lobes increased in length but dependent on the extent of lobe growth (1 transect in 1985, 1 in 1989 at SS; 2 transects in 1986 at NS). From the initial 1984 stakes, each subsequent transect stake was separated by ~50 m down lobe from the first stake. Thus by the 1989 summer, three transect locations at SS and NS were established for plot sampling until study completion. The plant biomass samples were usually taken in August at the end of the growing season (21 of the 25 years to 2008), but always by the end of the first week in September. August end is the time the vast majority of the marsh community finishes flowering; and autumn wetland senescence occurs from mid-September to October. The exact timing of sampling over the 2.5 decades avoided dangerous stormy peri-